*EMISSION-LINE OBJECTS PROJECTED UPON THE GALACTIC BULGE**

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Abstract.—Low-dispersion slit spectrograms have been obtained of 34 faint objects that lie in the direction of the galactic bulge and have the Hα line in emission upon a detectable continuum. Eleven of these are certain or probable symbiotic stars. A rough comparison with R CrB stars in the same area suggests that these brightest symbiotics in the bulge have in the mean $M_v \approx -3$ to -4, which suggest Population II red giants rather than conventional Population I M-type objects. The sample also contains a number of hot stars having H and [O II] or [O III] in emission, as well as four conventional Be stars, and six certain or possible planetary nebulae.

The well-known concentration of certain objects, such as faint planetary nebulae and RR Lyrae stars, toward the galactic bulge is an index of their population characteristics and also serves in principle as an indicator of their absolute magnitudes. Stars having strong line emission at Hα are not ordinarily regarded as members of the bulge population, presumably on account of their absence from globular clusters. But the fact that the total stellar content of the bulge is 10^3 or more times higher than that of the totality of observable globular clusters could well raise the frequency of a rare species to a detectable level. Since a small number of emission-Hα stars have in fact been found projected upon the bulge, it is of interest to determine their nature.

The emission-Hα stars observed here all lie within about 15° of the galactic center. Excluded from the outset were all objects known with assurance to be planetary nebulae. Included were stars which showed a detectable continuous spectrum on Hα-objective prism plates, a criterion that in itself works against most planetaries.[1]

In order to apply this latter condition, I was very fortunate in being permitted in 1961 to examine the Tonantzintla objective-prism spectrograms of the bulge area and am very much indebted to Messrs. G. Haro, B. Iriarte, and E. Chavira for this courtesy. Also excluded were emission stars brighter than a magnitude of 10, because an unpublished spectroscopic examination of some 18 stars in this magnitude interval made by Dr. L. V. Kuhi in 1959 had shown that all those were foreground Be stars lying in the Sagittarius arm. The same conclusion had been reached earlier by Minkowski[2] from the latitude distribution of Be stars in this direction.

Low-dispersion (430 Å/mm at Hγ) slit spectrograms of the 34 objects listed in Table 1 were obtained in 1958–63 at the Crossley reflector. The stars are listed in column 1 whenever possible by their MWC[3] or AS[4] numbers, the others being Tonantzintla discoveries either published by Iriarte and Chavira[5] or unpublished (prefixed by a *T*). The second column contains the designation assigned by

TABLE 1. *Catalogue of objects.*

	Designation*	m_{pg}	α (1900)			δ (1900)			$d\alpha/dt$ (sec/yr)	$d\delta/dt$ ($''$/yr)	Classification	Footnote
T 41	—	11	17^h	33^m	13.7^s	−28°	32′	40″	$+3^s.796$	−2″.20	Be	(1)
T 42	—	11	17	38	07.9	−30	06	16	+3.845	−1.77	Be	(1)
—	7 +1° 2(†)	14*n*	17	51	15.4	−21	40	39	+3.604	−0.64	SS	(2)
Ir-Ch 3	—	13	17	53	00.9	−23	13	54	+3.647	−0.48	Cont.	(3)
AS 265	—	11	17	55	07.7	−29	19	15	+3.824	−0.29	Be	(1)
AS 268	—	14	17	56	17.7	−23	34	31	+3.656	−0.20	WR?	(4)
AS 269	358 −5° 2	14:	17	56	50.8	−32	42	24	+3.931	−0.14	G-Keγ	(5)
—	358 −5° 3	13?*nn*	17	57	20.2	−32	41	47	+3.931	−0.09	Pl. neb.	(6)
T 17	—	15*n*	18	00	42.3	−29	37	05	+3.833	+0.21	SS?	(7)
AS 272	2 −4° 1	16	18	00	45.1	−29	13	42	+3.821	+0.21	Pl. neb.	(8)
T 53	—	13	18	01	19.7	−25	54	23	+3.722	+0.26	SS?	(9)
AS 278	8 −1° 1	17?*nn*	18	02	23.8	−22	17	41	+3.621	+0.35	Pl. neb.	(10)
—	3 −4° 2	14	18	04	10.1	−28	08	45	+3.788	+0.51	Be?	(11)
AS 281(†)	3 −4° 1	15	18	04	25.5	−27	58	56	+3.783	+0.53	SS?	(12)
AS 283	3 −4° 7	13	18	05	15.5	−28	23	51	+3.795	+0.60	Be?	(13)
AS 286	—	10	18	05	57.9	−25	09	52	+3.701	+0.66	Be	(14)
AS 290(†)	359 −6° 1	15	18	06	46.0	−32	21	10	+3.919	+0.74	Cont. +e	(15)
AS 292(†)	—	13	18	07	36.9	−32	49	06	+3.934	+0.81	Ke	(16)
AS 293	2 −5° 1	14	18	08	10.6	−29	51	03	+3.839	+0.86	SS?	(17)
—	1 −6° 1(†)	13*n*	18	08	58.5	−30	33	42	+3.861	+0.93	Cont. +e	(18)
MWC 288	1 −6° 2	12	18	09	45.0	−30	54	02	+3.872	+1.00	Pl. neb.?	(19)
—	4 −4° 2	13	18	10	01.7	−27	06	26	+3.756	+1.02	e	(20)
AS 299(†)	—	14	18	11	01.4	−28	11	53	+3.788	+1.11	Cont. +e	(21)
AS 301	7 −4° 1	15	18	14	01.3	−24	17	34	+3.675	+1.36	Cont. +e	(22)
T 21	—	12	18	14	05.5	−26	25	17	+3.735	+1.37	SS	(23)
AS 302	—	13	18	14	59.5	−31	34	45	+3.892	+1.46	SS?	(24)
AS 303(†)	7 −6° 1	15*nn*	18	18	46.0	−25	45	08	+3.715	+1.78	Pl. neb.	(25)
—	11 −6° 1(†)	13	18	30	33.5	−21	53	55	+3.605	+2.80	Cont. +e	(26)
AS 313	—	15	18	31	59.3	−22	46	57	+3.628	+2.92	SS	(27)
AS 316(†)	12 −7° 1	14	18	36	33.9	−21	23	31	+3.589	+3.32	SS	(28)
MWC 957(†)	11 −9° 1	13	18	40	30.6	−23	33	07	+3.645	+3.66	Pl. neb.?	(29)
MWC 960(†)	—	13	18	42	00.2	−20	12	22	+3.556	+3.78	SS?	(30)
AS 325	—	10	18	43	51.0	−26	31	03	+3.726	+3.95	Feδ	(31)
AS 327	—	14	18	47	10.0	−24	30	15	+3.668	+4.23	SS	(32)

* By Perek and Kohoutek.[6]

† Illustrated in Fig. 1.

(1) *T 41, T 42, AS 265:* A B-type absorption spectrum is visible, but no emission is apparent in the photographic region.

(2) *7 + 1° 2:* The light variability and $H\alpha$ emission were discovered by Zwicky,[13] who estimated the photographic range as 14.6 − <17.6. The light variation was confirmed on Harvard plates about 1942 by Miss D. Hoffleit (private communication, 1958). She found that the object is normally faint but exhibited bright maxima in 1893, 1930, and 1941. I examined it visually on several occasions between 1958 and 1963 with the Crossley and 120-inch reflectors and suspected that a change of about 0.5 mag. may have taken place during this time. The object was regarded as a planetary nebula by Minkowski[14] and Velghe.[15] Two Crossley spectrograms taken in 1948 and 1958 (Fig. 1) show emission Hβ and He II λ4686 of equal intensity, with [O III] λλ4959, 5007, and the other Balmer lines being much weaker. The continuous spectrum is moderately strong. The object is probably a symbiotic star.

(3) *Ir-Ch 3:* Hα emission was discovered by Iriarte and Chavira.[5] An unwidened slit spectrogram of the photographic region shows only a continuous spectrum without emission lines.

(4) *AS 268:* The spectrum is nearly continuous, but there is weak emission at *Hβ* and a broad emission feature shortward of λ4686.

(5) *AS 269:* HB is strong and Hγ weak in emission on a continuum having the absorption lines of a G or K-type star.

(6) *358 −5° 3:* Certainly a planetary nebula. The following emission lines (with estimated intensities) are present on a weak continuum: [O III] λ5007 (60), [O III] λ4959 (20), Hβ (10), He II λ4686 (1), [O III] λ4363 (2), Hγ (4), Hδ (2), Hε + [Ne III] λ3968 (2), H8 (1), [Ne III] λ3867 (5), [O II] λ3727 (1).

(7) *T 17:* Very weak Hβ and λ4686 emission are present on a reddened or late-type continuous spectrum, possibly that of a K-type star.

(8) *AS 272:* Certainly a planetary nebula. Emission lines are present (on a weak continuum) with the following estimated intensities: λ5007 (20), λ4959 (8), Hβ (10), Hγ (5), Hδ (2), Hε (1), H8 (1), λ3727 (5).

(9) *T 53:* Weak [O III] λλ5007, 4959, Hβ, and [Ne III] λλ3968, 3867 emission lines are present on a strong continuous spectrum, possibly of G- or K-type.

(10) *AS 278:* A planetary nebula: only [O III] λλ5007, 4959, and Hβ appear and a very faint continuum.

(11) *3 −4° 2:* Hβ through H8 appear in emission with a steep decrement on a strong continuous spectrum. A faint line near 4670 A may also be present.

(12) *AS 281:* Hβ and λ4686 are intense in emission on a strong continuous spectrum, followed by other Balmer lines and possibly a weak λ3727. It is probably a symbiotic star (Fig. 1).

(13) *AS 283:* Hβ, Hγ, Hδ are in emission on a strong featureless continuum: it is probably a Be star.

(14) *AS 286:* A B-type star with very broad Balmer absorption lines and weak emission at Hβ.

(15) *AS 290:* The Balmer lines through H8 and [O II] λ3727 are in emission on a strong continuous spectrum (Fig. 1).

(16) *AS 292:* The type was given as K5e in the *Henry Draper Extension*, and Bidelman[16] has classified it dK5e, with H and Ca II in emission. No forbidden or high-excitation lines appear on the single Crossley spectrogram available (Fig. 1), so it cannot be a conventional symbiotic star.

(17) *AS 293:* The Balmer lines and λ4686 are in emission on a strong continuous spectrum.

(18) *1 −6° 1:* Strong H emission lines through H10 are present, followed by weak [O III] and [Ne III], and He II λ4686. The continuous spectrum is strong, but no absorption lines are apparent (Fig. 1). The classification is uncertain.

(19) *MWC 288* (= HD 167362): The spectrum has been described by Swings and Struve,[17] who regarded the object as a planetary nebula. On the single Crossley plate, the more intense bright lines listed by Swings and Struve are present on a strong continuous spectrum having the Balmer continuum in emission.

(20) *4 −4° 2:* Only the Balmer lines through Hδ can be seen in emission, displaced slightly in declination from the continuous spectrum of the G-type star at this position. The classification of this emission object is uncertain.

(21) *AS 299:* This object is not Nova Sgr 1954, as suspected in the *AS*. The Balmer lines through H9 are strong in emission, accompanied by very weak [O III], [Ne III], and HeI. The continuous spectrum is strong, but no absorption features are detectable with certainty, although the strongest TiO head may be present (Fig. 1).

(22) *AS 301:* Only the Balmer lines through Hϵ are present in emission on a featureless continuum.

(23) *T 21:* Hβ and λ4686 are weakly visible in emission on the continuum of a G- or K-type star; [O III] $\lambda\lambda$5007, 4959 may also be present.

(24) *AS 302:* The following emission lines are present on a strong continuous spectrum: [O III] λ5007 (4), λ4959 (2), Hβ (10), λ4686 + another line to shortward (2?), Hγ (3), Hδ (2), Hϵ (1). The spectrum was classified as "Pec" by Henize,[10] but no details were given. According to Minkowski,[2] the star is variable. An identification chart is given by McCuskey.[18]

(25) *AS 303:* This object is certainly a planetary nebula, having the following emission lines on a faint continuum: [O III], λ5007 (60), λ4959 (20), Hβ (10), λ4686 (15), Hγ (5), Hδ (3), Hϵ + [Ne III] (3), H8 (1), [Ne III] λ3967 (8), λ3727 (2) (Fig. 1).

(26) *11 −6° 1:* The following emission lines appear on a smooth continuum: Hβ (10), Hγ (5), Hδ (2), Hϵ (1), λ3727 (3). The classification is uncertain (Fig. 1).

(27) *AS 313:* A single Crossley spectrogram taken on Sept. 2, 1959, shows bright H and HeI lines, accompanied by HeII λ4686 and a few weaker emission lines, on an early M-type absorption spectrum. The light curve of this star has been studied by Miss Hoffleit,[19] who found cyclic variation reminiscent of CI Cyg with a period of 850 days between m_{pg} = 14.0 and 15.3. Warner and Swasey objective prism spectrograms classified by Miss Houk gave the type as M6 with Hα in emission.

(28) *AS 316:* Hβ and λ4686 are very strong on an M-type spectrum, followed by other Balmer lines through H9, and a trace of [O III] (Fig. 1).

(29) *MWC 957:* The following emission lines are present on a smooth continuous spectrum: [O III] λ5007 (10), λ4959 (4), Hβ (50), a line near λ4670 (3), Hγ (30), Hδ (20), [S II] $\lambda\lambda$4076, 4068, or C III (5), Hϵ (10), H8 (8), H9 (4), H10 (2), H11 (2), λ3727 (25). The object was regarded as a Be star by Vyssotsky, Miller, and Walther,[20] but as a planetary by Henize.[10] At this dispersion, it most resembles MWC 288 (Fig. 1).

(30) *MWC 960:* Hβ and λ4686 are the strongest emission lines on a smooth but low-temperature continuum, followed by the Balmer lines through H9. [O III] is absent, but [Ne III] may appear marginally (Fig. 1).

(31) *AS 325:* Hβ, Hγ, Hδ are bright on a strong continuous spectrum having H and K in absorption. At such low dispersion, classification of this star is not possible. Merrill and Burwell[3] described the type as Feδ.

(32) *AS 327:* Hβ and λ4686 are the strongest emission lines, followed by Hγ and Hδ, on what appears to be an early M-type spectrum. According to Henize,[10] the star has been classified as symbiotic also by Minkowski.

TABLE 2. *Summary of classifications of stars in Table 1.*

Classification	Number of stars
Certainly Be	4
Continuous with only H emission	4
Continuous with H and [O II] emission	2
Continuous with H and [O III] emission	2
Symbiotic (= SS)	5
Probably symbiotic (= SS?)	6
Planetary nebulae	4
Possibly planetary nebulae	2
Miscellaneous or unknown	5

Perek and Kohoutek[6] in those cases where the object had been regarded as a planetary nebula. The third column contains a rough estimate of the photographic magnitude, which is particularly uncertain for those objects having soft (*n*) or very diffuse (*nn*) images.[7] The next four columns give the accurate α, δ for 1900 and the annual precessional corrections for 1925.0. These positions were very kindly determined for me by Mr. C. A. Wirtanen from original plates obtained in the course of the Lick proper-motion program with the 20-inch Astrograph, using AGK 2 reference stars and the Lick-Gaertner automatic measuring machine. The next-to-last column contains the spectroscopic classification of each object, which is explained in the numbered notes following the table. A number of the spectra are reproduced in Figure 1, together with spectrograms of the standard symbiotic objects Z And, AX Per, and CI Cyg obtained with the same equipment.

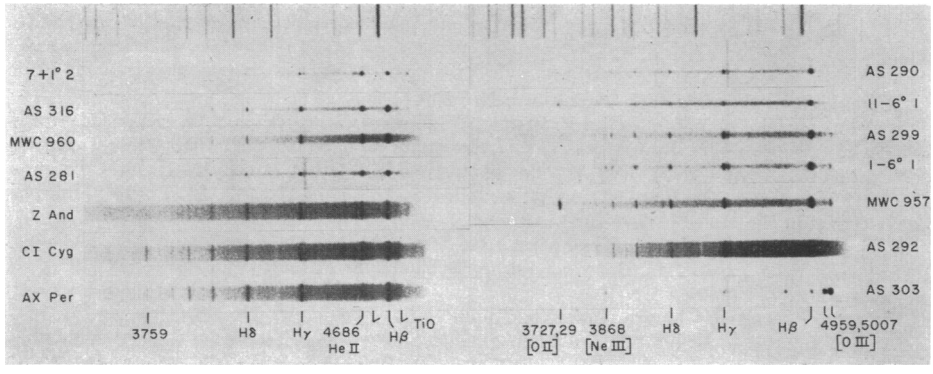

FIG. 1.—Low-dispersion spectrograms (reproduced as negatives) of 11 emission-line objects seen projected upon the galactic bulge; details of the individual spectra are described in the notes to Table 1. The spectra, obtained with the same equipment, of three bright symbiotic stars (Z And, CI Cyg, AX Per) are shown for comparison. The emission line crossing some of the spectra just longward of Hγ is scattered HgI λ4358 from artificial sources of illumination in the Santa Clara Valley.

The classifications of the galactic bulge stars are summarized in Table 2. Weak H and HeI absorption lines are not detectable on unwidened spectrograms at this dispersion, so that the spectra described as "continuous with only H emission" may be of unrecognized Be stars. Such faint (m_{pg} = 10 to 15) Be stars in this direction are presumably heavily obscured members of the Sagittarius arm or belong to inner arms.

The most interesting feature of Table 2 is the large number of certain or probable symbiotic stars projected upon the galactic bulge. The fact that Hα surveys were capable of detecting such objects was first pointed out by Minkowski,[8] and several of the bulge stars recognized as symbiotic by him in the course of the Mt. Wilson survey for planetary nebulae have been identified elsewhere.[4, 9, 10] The occurrence of significant numbers of symbiotic stars in that direction shows that at least some of them belong to the same old stellar population as do the planetary nebulae, novae, and R CrB variables.[11] The presence of symbiotic stars in Population II had originally been suggested by Tifft and Greenstein[12] on the basis

of the high-velocity, high-latitude symbiotic objects RW Hya and MWC 603. To these examples, one could now add the even more extreme case of AG Dra ($v_{rad} = -135$ km/sec, $b = +41°$). The suggestion, therefore, can now be regarded as firmly established.

The brighter symbiotic stars in Table 1 have $m_{pg} \approx 13$–14. This compares with $m_{pg} \approx 11$–12 at maximum light for the brighter R CrB variables in the same region. Since at maximum light the R CrB stars have $M_v \approx -4$ to -5, if the symbiotic stars in Table 2 lie at about the same distance (which is not proved), then they must have $M_v \approx -3$ to -4. This is certainly too luminous for a Population I M-type giant but is possible for a very bright Population II red giant, as was noted in the case of MWC 603 by Tifft and Greenstein. This is independent evidence of the membership of these symbiotic stars in an old stellar population.

The nature of the four stars in Table 1 that have continuous spectra with H and [O II] or [O III] emission lines is not clear; they deserve examination at higher dispersion.

* *Contributions from the Lick Observatory*, No. 299.

[1] The ultraviolet object found by V. Blanco, W. Kunkel, W. A. Hiltner, G. Lynga, H. Bradt, G. Clark, S. Naranan, S. Rappaport, and G. Spada (*Astrophys. J.*, **152,** 1015 (1968)) near the position of the X-ray source GX3 + 1 lies in this region. It has strong He II and OVI emission lines (Blanco, V., W. Kunkel, and W. A. Hiltner, *Astrophys. J.*, **152,** L137 (1968)) but was not detected in the Hα objective-prism surveys.

[2] Minkowski, R., *Publ. Obs. Univ. Mich.*, **10,** 25 (1951).

[3] Merrill, P. W., and C. G. Burwell, *Astrophys. J.*, **78,** 87 (1933); **110,** 387 (1949).

[4] *Ibid.*, **112,** 72 (1950).

[5] Iriarte, B., and E. Chavira, *Bol. Obs. Tonantzintla y Tacubaya*, No. 14 (1956), p. 31.

[6] Perek, L., and L. Kohoutek, *Catalogue of Galactic Planetary Nebulae* (Prague: Academia, 1967).

[7] Such images can be produced on 20-inch negatives either by a genuinely extended surface or as the effect of out-of-focus $N_{1,2}$ + Hβ or λ3727 light on an otherwise stellar image.

[8] Minkowski, R., in *Carnegie Yearbook*, No. 44 (1945), p. 14.

[9] Minkowski, R., *Publ. Astron. Soc. Pacific*, **58,** 305 (1946).

[10] Henize, K. G., *Astrophys. J. Suppl.*, **14,** 125 (1967).

[11] Since the symbiotic stars have now been shown with some certainty to be binaries (e.g., Boyarchuk, A., *Astrofizika*, **2,** 101 (1966)), this also demonstrates that close binaries do exist in this old population.

[12] Tifft, W. G., and J. L. Greenstein, *Astrophys. J.*, **127,** 160 (1958).

[13] Zwicky, F., in *Morphological Astronomy* (Berlin: Springer, 1957), p. 241.

[14] Minkowski, R., *Publ. Astron. Soc. Pacific*, **60,** 386 (1948).

[15] Velghe, A. G., *Astrophys. J.*, **126,** 302 (1957).

[16] Bidelman, W. P., *Astrophys. J. Suppl.*, **1,** 175 (1954).

[17] Swings, P., and O. Struve, these PROCEEDINGS, **26,** 454 (1940); *Astrophys. J.*, **97,** 194 (1943).

[18] McCuskey, S. W., *Publ. Astron. Soc. Pacific*, **73,** 264 (1961).

[19] Hoffleit, D., *Inf. Bull. Var. Stars*, No. 254 (1968); *Irish Astron. J.*, **8,** 149 (1968).

[20] Vyssotsky, A. N., W. J. Miller, and M. E. Walther, *Publ. Astron. Soc. Pacific*, **57,** 314 (1945).